ADAPTIVE SEARCHER THRESHOLD SETTING USING CONSECUTIVE ISCP MEASUREMENTS

FIELD OF THE INVENTION

The present invention relates to third generation CDMA mobile systems, and more particularly to adapting searcher thresholds in a CDMA base band receiver using only interference signal code power (ISCP) measurements.

BACKGROUND OF THE INVENTION

Third generation code division multiple access (CDMA) mobile systems, such as Universal Mobile Telecommunication System (UMTS) Third Generation Partnership Program (3GPP) wideband code division multiple access (W–CDMA), use searcher thresholds to detect propagation paths while ensuring a constant probability of false alarm.

One conventional system for ensuring a constant probability of false alarm involves minimizing automatic gain control (AGC) jittering using highly accurate analog components. A disadvantage to this approach is the increased system cost due to the high cost of highly accurate analog components.

Another conventional system involves adding additional digital hardware for measuring the total of the received-signal power plus the interference power, after analog-to-digital (A/D) conversion, and feeding back the measured total-received-signal-plus-interference power to the AGC or use the measured value directly to normalize the power measurements. A disadvantage of this approach is the need for additional hardware and its attendant expense.

Both of these conventional systems will only allow normalization based on a combined measurement of both signal and interference power. However, in order to ensure a constant

probability of false alarm, the normalization should ideally happen based only on the interference power.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a method for dynamically adjusting searcher thresholds in a base band receiver, the searcher thresholds being used to detect propagation paths of a communications signal transmitted from a transmitter to the base band receiver. Interference signal code power (ISCP) measurements of the communications signal are obtained from a database communicatively coupled with the base band receiver, wherein contents of the database are associated with a physical layer. A scaler is calculated based on the ISCP measurements only. The searcher thresholds, which are stored in the database, are adjusted using the scaler. The adjusted searcher thresholds are then stored in the database.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a block diagram of an overview of a portion of a third-generation CDMA mobile system;

Fig. 2 illustrates a block diagram of a propagation path detection process; and

Fig. 3 illustrates a flowchart for adapting searcher thresholds based on ISCP measurements according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED MODE OF THE INVENTION

By way of overview, the present invention provides a method and apparatus for dynamically adjusting searcher thresholds based on a transformation using a non-orthogonal interference signal code power (ISCP) measurement. Because the ISCP measurement is based on only interference power and not signal power, there is a constant probability of false alarm

even for relatively high signal power. Moreover, because the ISCP measurements are readily available at the L1 processor, no additional hardware is needed.

The present invention is described by first providing an overview of a portion of a third-generation CDMA mobile system, followed by a description of propagation path detection, probability of false alarm, and physical layer measurements, and finally a description of adapting searcher thresholds according to the preferred mode of the present invention.

A. Overview of Portion of Third-Generation CDMA Mobile System

Fig. 1 illustrates a block diagram of an overview of a portion of a third-generation CDMA mobile system 100, including an automatic gain control (AGC) 101, an analog-to-digital (A/D) converter 102, a third-generation (3G) digital base band receiver 103, and a physical layer (L1) processor 104. Optimum usage of the digital base band receiver 103 requires constant average power level of a digital input signal r_n. The same applies to the analog input signal of the A/D converter 102. To ensure a fairly constant power level over time, the received analog signal r(t), which is the total received signal power of all mobile phones plus thermal noise, is scaled by the AGC 101. The AGC 101 typically scales the analog signal r(t) by comparing a filtered analog power measurement of the analog signal r(t) against a predefined target power known as an AGC set-point α. The accuracy of the AGC 101 is limited due to temperature effects and aging of its analog components.

The digital base band receiver 103 of Fig. 1 contains a RAKE receiver (not shown), which scans a power delay profile of the digital input signal r_n for resolvable propagation paths using searcher thresholds (which are dynamically adapted, that is, set by a preferred mode of the present invention); accurate power measurement during this scanning is essential. The

underlying processing of this scanning task is a core task of finger management, which is performed as represented in L1 processor 104.

Physical layer measurements provided by the base band receiver 103 are stored in the L1 databases 104-1 of L1 processor 104 and are used for various L1 processing algorithms 104-2 and 104-3. One of these algorithms is the RAKE receiver finger management algorithm 104-2, which uses both finger energy measurements and adaptive searcher threshold settings 104-4, which are based on ISCP measurements, to calculate values used to configure the base band receiver 103. The searcher thresholds are adaptive in order to account for jitter in the AGC 101.

B. Propagation Path Detection

Fig. 2 illustrates a block diagram of a propagation path detection process 200 performed by the RAKE receiver portion 103-1 of the base band receiver 103. Path power is measured by a correlator 201 correlating a complex received signal r_n at chip level with an expected training sequence c_n, where n is a time index. The training sequence c_n may be composed of a scrambling code, a channelization code, and a pilot pattern, and is a sequence of data bits known to the base band receiver 103. Because the receiver 103 knows the expected training sequence, it can measure and compare the actual received sequence with the expected training sequence, to thereby obtain a distortion characteristic (i.e., correlation signal) of that particular channel.

Summer 202 coherently integrates the correlation signal from correlator 201 over the training sequence length N to produce x_m, which is the complex correlation of the received signal r_n with training sequence c_n. Error detector 203 then non-coherently integrates the mean square error (MSE) of x_m over M accumulations of the energy measurement to produce detection variable z, which is a measure of the ISCP plus signal. Finally, comparator 204 compares the

detection variable z with threshold T. If detection variable z is greater than threshold T, then a valid propagation path is detected; otherwise, no valid propagation path is detected.

At the end of an observation period, thresholds T are used to identify a certain time offset as a valid propagation path. Multiple correlation results may be combined non-coherently per observation period. The characteristic design parameters associated with a threshold T are probability of detection (i.e., power measurement exceeding threshold T at valid time offset, that is, when the signal is present) and probability of false alarm (i.e., power measurement exceeding threshold T at invalid time offset, that is, when the signal is absent and only noise is present).

The maximum number of paths is determined by the RAKE receiver portion 103-1. Valid propagation paths may be stored in a database such as 104-1, sorted, and then the propagation paths having the highest detection variable z may be selected. However, history may also be taken into account resulting in certain propagation paths with the highest detection variables not being selected; this is known as rules-based selection. Reasons for not selecting a propagation path with a high detection variable z include, but are not limited to, a likelihood that two propagation paths will merge into one another, or that a propagation path will extinguish at a certain point.

C. Probability of False Alarm

Typically, the observation period and thresholds are chosen such that the probability of false alarm stays below a certain value (e.g., $1e^{-4}$) while still ensuring an acceptable probability of detection (i.e., > 0.9) depending on available signal power. The knowledge and constancy in particular of the probability of false alarm is essential for allowing efficient finger management and thus important for the overall performance of the digital base band receiver 103.

Both the probability of detection and probability of false alarm are highly sensitive with respect to changes in the ratio of signal-plus-interference power to threshold setting. AGC gain above the target set-point α will cause an increased probability of false alarm, eventually leading to additional interference due to contribution of invalid propagation paths. AGC gain below the target set-point α will result in a decreased probability of detection and thus loss of valid propagation paths. Thus a core challenge is to maintain a certain probability of false alarm across the expected dynamics of signal and interference power, including the impact of AGC.

The probability of false alarm can be written as:

$$p_{fa} = e^{-\frac{T}{2\sigma_x^2}} \cdot \sum_{m=0}^{M-1} \frac{1}{m!}\left(\frac{T}{2\sigma_x^2}\right)^m \qquad (1)$$

where p_{fa} is the probability of false alarm, and $2\sigma_x^2$ is the combined variance of x on I and Q phase.

The interference signal code power (ISCP) is defined as the non-orthogonal interference signal code power measured on the code channel (DPCCH), that is, the Q phase only. Assuming the ISCP measurement is normalized to chip level, σ_x^2 can be expressed as:

$$\sigma_x^2 = N \cdot ISCP \qquad (2)$$

where N is the total length of the training sequence. Equation (2) incorporated into Equation (1) can be expressed as:

$$p_{fa} = e^{-\frac{T}{2N \cdot ISCP}} \cdot \sum_{m=0}^{M-1} \frac{1}{m!}\left(\frac{T}{2N \cdot ISCP}\right)^m \qquad (3).$$

Equation (3) is an important foundation of the invention, that is, that there is a constant probability of false alarm p_{fa} for a constant ratio of T/ISCP.

Also, no additional hardware is required to detect ISCP because ISCP is already known at the base band receiver 103 as it is calculated for other 3GPP layers and the ISCP measurement used in these calculations is stored in Layer 1 database 104-1. More specifically, UMTS Terrestrial Radio Access Network (UTRAN), which is a term describing radio network controllers and node base stations of a UMTS network, requires measurement of signal-to-interference ratio (SIR), which is defined as:

$$SIR = \frac{RSCP}{ISCP} \cdot SF \tag{4}$$

where RSCP is the measurement of received signal code power, and SF is the spreading factor on the code channel (DPCCH), and it is in this measurement that ISCP is used and for which it has already been measured.

D. Physical Layer Measurements

The 3GPP standard does not dictate how measurements are executed in the physical layer (L1), however, the standard does dictate the reporting period and accuracy of the measurements. For the SIR measurement, the 3GPP, TS 25.133 V5.7.0 standard requires a reporting period of 80ms and an accuracy of +/-3dB for -7dB < SIR < 20dB.

UTRAN requires a SIR measurement for every uplink connection. The uplink received signal is composed of a superposition of all U uplink connections plus thermal noise of power N. The total received signal power S at chip level is represented as:

$$S = \sum_{u=0}^{U-1} RSCP_u + N \tag{5.}$$

The ISCP for each uplink connection is represented as:

$$ISCP_u = S - RSCP_u \tag{6.}$$

At chip level the contribution of an individual uplink connection is typically negligible with respect to the overall power of the received signal (i.e. $RSCP_u << S,\ u \in [0,..,U-1]$). Thus the following relationship is obtained:

$$ISCP_u \approx S, u \in [0,..,U-1] \qquad (7).$$

According to Equation (7), all uplink connections have almost the same interference signal code power. Thus, it is possible to take the average of the ISCP measurements across all uplink connections to improve the measurement accuracy, that is,

$$ISCP = \frac{1}{U}\sum_{u=0}^{U} ISCP_u \qquad (8).$$

E. Adapting Searcher Thresholds According to the Preferred Mode

The present invention will now be described with respect to a preferred mode having a UTRAN with 24 (i.e., U=24) active uplink connections. As required by the 3GPP, the physical layer (L1) provides one ISCP measurement per 80ms for each uplink connection. For the sake of the following discussion, it is assumed that each uplink connection has a path assignment update every 40, 60, or 80ms.

1. Initial Calibration of ISCP

The initial calibration of ISCP involves four steps, as described in the following paragraphs.

The first step is to select an automatic gain control (AGC) set-point α based on expected dynamics of the received signal r(t) and the characteristics of the A/D converter 102. That is, the AGC set-point α is set such that the signal input to the A/D converter 102 is within the operating range of the A/D converter 102.

The second step is to determine, for each uplink connection (u= 1...U), the initial threshold T_u that provides a desired probability of false alarm for the chosen AGC set-point α. The desired probability of false alarm should ideally be within the range of 1×10^{-4} and 1×10^{-3}.

The third step is to select a common update period for adjusting searcher thresholds. The searcher thresholds must remain constant during a path assignment period of the respective uplink connection. Thus, the common update period should be an integer multiple of different path assignment periods used in the receiver. If it is assumed that each uplink connection has a path assignment update every 40, 60, or 80ms as discussed above, then an acceptable update period (t_{update}) would be 240ms, because it is an integer multiple of 40, 60, and 80ms.

Finally, the fourth step is to measure the total average ISCP corresponding to the initial AGC set-point α. The measurement can be obtained while calculating the desired probabilities of false alarm for each uplink connection. To get the total average ISCP, the ISCP 80ms measurements for all uplink connections are integrated over t_{update} and then averaged across all uplink connections.

2. Adapting Searcher Thresholds Based on ISCP Measurements

Figure 3 illustrates a flowchart 300 for adapting searcher thresholds based on ISCP measurements according to the preferred mode of the present invention. This adaptive algorithm is an example of the adaptive threshold setting algorithm performed in the L1 processor 104 of Fig. 1.

The L1 databases 104-1 provide ISCP measurements (ISCP_80ms) for each finger in each uplink connection (u = 0 to U-1) every 80 ms. Each of summers 301-0 to 301-U-1 sums the ISCP measurements of all fingers (m = 0 to M-1) of the respective uplink connections to provide individual uplink ISCP sums. Summer 302 then sums the individual uplink ISCP sums to produce a total ISCP (x).

Normalizer 303 then normalizes the total ISCP (x) over y, which is the number of uplink connections U times the number of threshold updates (t_{update}) per 80ms measurements. More specifically, the number of uplink connections U times the threshold update t_{update} divided by 80ms is stored in buffer 304; the normalizer 303 divides the total ISCP (x) by the value stored in buffer 304 (i.e., y, or total ISCP·80ms/U·t_{update}) to calculate the normalized value of the total ISCP (x') for the present observation period.

Scaler calculator 305 then divides the normalized value of the total ISCP (x') by a previous normalized value of the prior observation period total ISCP (y'), which has been stored in ISCP buffer 306, to calculate a scaler value (x"). Scaler 307 then obtains previous searcher thresholds (y") for each of the uplink connections (u = 0 to U-1) from a searcher threshold database 308, scales each the previous searcher thresholds (y") for each of the uplink connections using scaler value x" by multiplying the scaler value x" by each of the previous searcher thresholds (y"), and restores the scaled searcher thresholds back in the searcher threshold database 308, thereby adjusting for the jitter in the AGC 101 (shown in Fig. 1). These scaled searcher thresholds are then used as the newly-adapted search thresholds used to detect propagation paths in a communications signal.

While the invention has been described in detail with particular reference to certain embodiments thereof, the invention is capable of other and different embodiments, and its details are capable of modifications in various obvious respects. As would be readily apparent to those skilled in the art, variations and modifications can be affected while remaining within the spirit and scope of the invention. Accordingly, the foregoing disclosure, description, and drawing figures are for illustrative purposes only, and do not in any way limit the invention, which is defined only by the claims.